Superposition of Waves

The purpose of this exercise is to have you become familiar with the ***principle of superposition*** or the rule of addition of waves. When two or more waves interfere with each other the amplitude of the resulting wave is the algebraic sum of the individual amplitudes. This exercise will let you experiment with the addition of both periodic waves and wave pulses and relate those investigations to sound.

INITIAL SET-UP OPEN EXCEL AND CHOOSE TOOLS/MACRO/SECURITY CHOOSE MEDIUM LEVEL SECURITY.

- Open the **dduncan** on the desktop. Choose **Physics** then click on **SuperPosition.xls.** When opening the file, choose **READ ONLY** then choose **ENABLE MACROS**. Click the button to go to the Contents and Instructions page. When you close this File **DO NOT SAVE CHANGES**.
- Answer the lab questions by inserting the appropriate text in the **spaces provided on page 3 and 4 of this** document. For the questions that involve a wave sketch, add your sketch by hand after your *Word* document prints.

EXERCISE 1: WAVE PULSES

- Click the button or tab labeled, **Waves in Motion**.
- Select a pair of waves by clicking one of the option buttons. Select Equal Amplitude option and then click the Reset Waves button.
- Try to predict what you will observe when these two waves moves toward each other.
- Check your prediction by clicking the Wave Motion button.
- Click the Unequal Amplitude option button and repeat the experiment.
- Choose a different set of waves and repeat the observations.

Enter your answers to questions 1 through 3 on the table in the **last 2 pages of this** document.

Q1- List all wave combinations that produce total destructive interference at one point in the motion.

Q2- List all wave combination that produce only constructive interference.

Q3- List all wave combinations that produce both constructive and destructive interference.

EXERCISE 2: PERIODIC WAVES, SOUND

- Click the button or tab labeled, **Superposition**. You will see a table and two graphs. The graph on the left displays from 1 to 6 waves. The graph on the right shows the resulting superposition of those waves. You will be able to control the amplitude, frequency, and phase of each wave.

Amplitude:	The displacement of the wave above or below the axis. When referring to the wave as a whole, *amplitude* means the maximum displacement above or below the axis.
Frequency:	The number of full cycles (waves) completed in one second (Hz).
Phase:	The waves on this worksheet are sine waves. The phase of the wave will refer to the angle along the sine wave at the start of the wave cycle.

- When you first open the Superposition worksheet only Wave 1 will be active. It will have amplitude of 1, a frequency of 1, and a phase of 0°. The wave completes one cycle in 360°.
- Click on the table above the graphs and change the frequency, amplitude, and phase of this wave until you understand the behavior of the three parameters. If this wave represented a sound wave it would be a pure tone.
- Reset the amplitude of Wave 1 to 1, its frequency to 1, and its phase to 0°. Set the amplitude of Wave 2 to 0.5 and its frequency to 1. Leave the phase at 0°. Notice that both waves are displayed on the left. The graph to the right shows the superposition of these two waves.

Q4- What is the maximum amplitude of the resulting wave on the right?

Q5- How does this compare to the amplitudes of Wave 1 and Wave 2?

- Change the amplitude of Wave 2 to 1, its frequency to 5, and its phase to 180°.

Q6- What is the resulting amplitude at 90° and 270°?

Q7- How does this compare to the amplitudes of Waves 1 and 2?

Notice that the resulting wave is still a pure tone of one frequency. It represents two sounds of the same frequency, but different loudness. Change the amplitude of Wave 2 to 1, its frequency to 2, and its phase to 0°.

Q8- Sketch the resulting wave.

✎ Change the phase of Wave 2 to 90°.

Q9- Again sketch the resulting wave.

✎ Experiment with only the phase of Wave 2.

Q10- At what phase do you see the most points of zero amplitude?

When a sound is made up of different frequencies, the lowest frequency is called the *fundamental*. If the higher frequency is a whole number multiple of the fundamental it is called a *harmonic*. The combination of waves that you just observed represent two sounds that are 1 octave apart.

✎ Place the mouse pointer over the word INSTRUCTIONS and perform the Easy Challenges.

Q11- Sketch the individual waves for each of the Easy Challenges.

Q12- Sketch the resulting wave for each of the Easy Challenges.

Q13- What happens when two sounds of the same frequency are out of phase by 180°?

✎ Set the following parameters for Waves 1 and 2.

Wave	1	2
Amplitude	1	1
Frequency	10	2
Phase	0°	0°

✎ Observe the superposition of the two waves. Change the amplitude of Wave 1 to 3 and observe the superposition graph. Change the amplitude to 0.5 and again observe. Try a few other values.

Q14- State a conclusion based on your observations and relate it to sound.

The amplitude of a sound wave is loudness. When two different sound waves have almost the same frequency a listener hears a pulsing variation of loudness. This is called a *beat.* The frequency of the beat is the difference in the frequencies of the two waves. When musical instruments are tuned they are compared to a standard note and then adjusted until the beat disappears.

✎ Set the following parameters for Waves 1 and 2.

Wave	1	2
Amplitude	1	1
Frequency	20	12
Phase	0°	0°

✎ Observe the superimposed wave. Change the frequency of Wave 2 to 13 and again observe. Continue to increase the frequency of Wave 2 by 1 until you reach 19.

Q15- Explain what you observed.

✎ Change the phase of Wave 2 to 90°, 180°, 270°, and 360°.

Q16- How many beat cycles are in 360°?

✎ Change the frequency of Wave 1 to 40 and Wave 2 to 38. Set the phase of Wave 2 to 180°.

Q17- How many beat cycles are completed in 360°?

✎ Change the frequency of Wave 2 to 39.

Q18- How many beat cycles are completed in 360°?

Q19- How many beat cycles are there when the frequency is 37? What about 36?

Q20- State a general principle about the number of beat cycles and the frequency of the 2 waves.

✎ Place the mouse cursor over the word INSTRUCTIONS. Try the Harder Challenge. Use all 6 waves to create the best square wave that you can.

Q21- Reproduce the data table for your six waves.

Q22- Sketch the resulting wave.

SUPERPOSITION OF WAVES

Q1 – Q3: Mark the appropriate box with an X.

	Q 1		Q 2		Q 3	
	equal amp.	unequal amp.	equal amp.	unequal amp.	equal amp.	unequal amp.
Half Sine						
Reverse Half Sine						
Sine						
Reverse Sine						
Square						
Reverse Square						
Triangular						
Reverse Triangular						

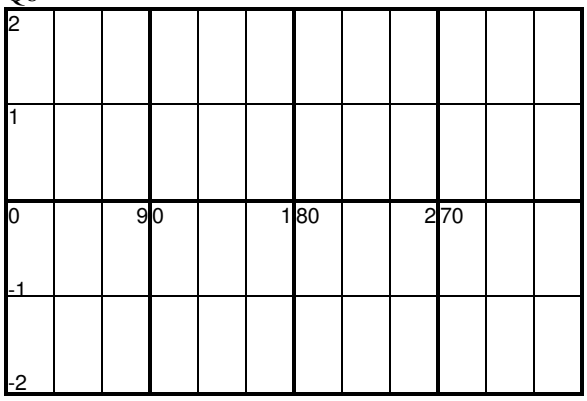
Q4-

Q5-

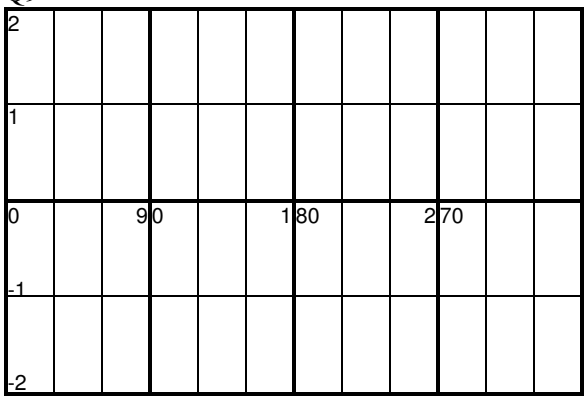
Q6-

Q7-

Q8-

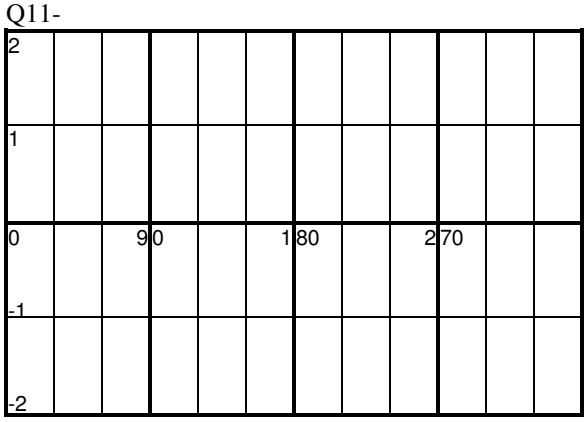


Q9-

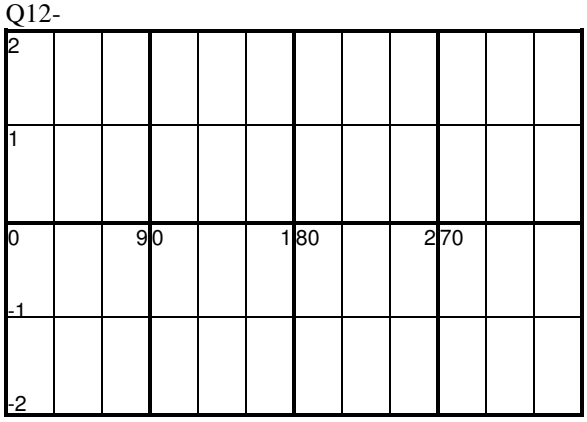


Q10

Q11-



Q12-



Q13-

Q14-

Q15-

Q16-

Q17-

Q18-

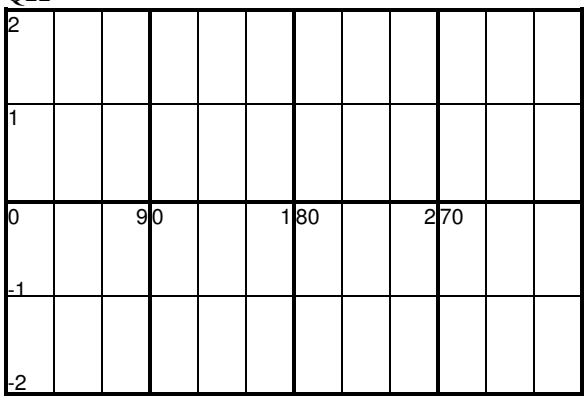
Q19-

Q20-

Q21-

WAVE	1	2	3	4	5	6
amplitude						
frequency						
phase						

Q22-



Q23 CONCLUSION: By manipulating the AMPLITUDE. FREQUENCY and PHASE ANGLE of the three WAVES available to you, try to create a "Square Wave", A square wave is important in electronics and should look something like the chart shown below. If you are successful, show me your best effort. You can not print this because of the black background.

DD's signature goes here. _____